Research Note

Incidence of Unabsorbed Yolk Sacs in Broilers, Broiler Breeder Roosters, White Leghorn Hens, and Athens-Canadian Randombred Control Broilers

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ABSTRACT Unabsorbed yolk sacs are being investigated as a possible reservoir for internal *Campylobacter* and salmonellae contamination of processed poultry carcasses. However, it is unknown at what frequency that unabsorbed yolk sacs persist at the time of processing of broilers and spent breeders. Seven sets of 100 broiler carcasses (at 6 or 8 wk of age) were obtained from commercial processing plants. In addition, 100 52-wk-old broiler breeder males, 100 102-wk-old Leghorn hens, and 300 8-wk-old Athens-Canadian randombred control (ACRBC) broilers were euthanized, and their abdominal cavities were opened for determination of the presence of unabsorbed yolk sacs. Carcasses with obliterated yolk stalks or stalks with no detectable yolk material were categorized as normal. Those with unabsorbed yolk sacs were further separated into 2 groups: 1) attached by the yolk stalk to the small intestine or 2) unattached within the abdominal cavity. Yolk sacs were further classified by size: 1) small was <2 mm in diameter, 2) medium was 2 to 10 mm, and 3) large was >10 mm. From the 300 commercial broiler carcasses that were 6 wk old, 54% were categorized as normal with no detectable yolk sac, 35% had an unabsorbed yolk sac attached to the yolk stalk, and 12% had unattached yolk sacs. From the 400 commercial broiler carcasses that were 8 wk old, 49% of the carcasses were normal, 31% had attached unabsorbed yolk sacs, and 20% had unattached yolk sacs. From the 100 rooster carcasses sampled, 73% were normal, 8% had attached unabsorbed yolk sacs, and 19% had unattached yolk sacs. From the 100 White Leghorn hen carcasses sampled, 88% were normal, 8% had attached unabsorbed yolk sacs, and 4% were unattached yolk sacs. From the 300 ACRBC carcasses sampled, 76% were normal, 4% had attached unabsorbed yolk sacs, and 20% were unattached yolk sacs. The incidence of unabsorbed yolk sacs in present day commercial broilers appears twice as high as for mature roosters, hens, or ACRBC broilers.

Key words: unabsorbed yolk, broiler, broiler breeder, Leghorn hen, Athens-Canadian randombred control broiler

2006 Poultry Science 85:1294–1297

INTRODUCTION

The egg yolk provides the developing embryo with nutrients from the time of extraembryonic vascularization and formation of the yolk sac (vitelline sac) on d 2 of incubation through hatch. The internalized yolk sac continues to provide nutrients to the chick posthatch, and the yolk sac content is typically completely absorbed by 10 to 14 d posthatch and converted into scar tissue (Latimer, 1924; Romanoff, 1960; Tur et al., 1986). However, in some chicks the yolk sac is not completely absorbed, and a portion remains unabsorbed in the abdominal cavity indefinitely. The specific causes for the incomplete yolk sac absorption are unclear. It has been suggested that unabsorbed yolk sacs may persist following prompt chick placement and the availability of feed and water soon after hatch (Mukarami et al., 1992). However, other studies have shown more rapid use rate of the yolk sac when feed and water are available (Heywang and Jull, 1930; Bierer and Eleazer, 1965; Feher and Gyuru, 1972; Noy et al., 1996). The consumption of feed increases gastrointestinal activity and chick metabolism, which may explain the more rapid secretion of yolk sac contents through the vitelline duct into the intestines of fed chicks (Feher and Gyuru, 1971). However, the absorption rate from the yolk sac into the blood circulation remains independent of posthatch feed intake (Mukarami et al., 1992). Causes for unabsorbed yolk sacs other than inhibited metabolic use may be influenced by the rate of lymphocyte infiltration during conversion of the umbilical stalk into lymphopoietic tissue and the concurrent regression in the diameter of the yolk duct that connects the yolk sac to the lumen of the small intestine (Olah and Glick, 1984). The prevalence of unabsorbed yolk sacs in ostrich chicks is thought to be linked to prior suboptimal incubation conditions of low oxygen, high temperature, and high relative humidity (Deeming, 1995; Speer, 1996). In addition, bacterial infection of the yolk and yolk stalk (omphalitis) can result

Received December 7, 2005.
Accepted March 13, 2006.
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in relatively larger unabsorbed yolk sacs in posthatch chicks (Speer, 1996).

It is unknown at what frequency that unabsorbed yolk sacs persist in present day commercial broilers or broiler breeders. The contents of the yolk sac pre- and posthatch are transported across the epithelial lining into the blood capillaries of the yolk sac. In addition, beginning on d 19 of incubation, yolk sac contents are transported directly into the lumen of the small intestine through the yolk stalk duct (ductus vitellinus; Esteban et al., 1991a,b; Jeurissen et al., 1991; Noy et al., 1996). If the yolk and its membrane are contaminated with *Salmonella* or *Campylobacter* during egg formation, then the potential exists for these pathogens to reach the intestinal lumen (avoiding the acidic proventriculus and gizzard environment) and thereby colonize the intestinal tract of the chick before and after hatching. Furthermore, an attached yolk sac may become colonized by bacteria from the intestinal lumen of the chick during the first 2 wk after hatching. A contaminated unabsorbed yolk sac may also serve as a reservoir for subsequent pathogen recolonization of the intestine or contamination of the abdominal cavity if ruptured during processing.

The possibility of vertical transmission of *Campylobacter* and *Salmonella* via yolk sacs is currently being reexamined (Cox et al., 2005). Desmidt et al. (1997) reported that the unabsorbed yolk sac and the granulomatous nodules in the ceca are possible reservoirs for *Salmonella enteritidis* contamination and would account for intermittent fecal shedding of *Salmonella* by the carrier birds during periods of stress. *Salmonella* are commonly isolated from the yolk sacs of 1-d-old turkey poults and broiler chicks (Hoover et al., 1997). The persistence of unabsorbed yolk sacs was concluded to be one result of natural *S. enteritidis* infection in broilers (O'Brien, 1988). Also, Gorham et al. (1994) described unabsorbed yolk sacs as "enlarged and firm" and among the most common lesion resulting from oral inoculation of 1-d-old chicks with *S. enteritidis.* Desmidt et al. (1997) demonstrated that chicks orally inoculated with *Salmonella* at 1 d of age had yolk sacs that were contaminated with *Salmonella* 4 wk following inoculation.

The following study was conducted to determine the incidence at which unabsorbed yolk sacs exist in today's commercial broilers, Athens-Canadian randombred control (**ACRBC**) broilers with 1950s genetics (Merritt and Gowe, 1962), and end-of-production commercial broiler breeder roosters and White Leghorn hens. Knowledge of the incidence of unabsorbed yolk sacs could assist in determining the potential risk of bacterial pathogen transmission by unabsorbed yolk sacs during processing.

MATERIALS AND METHODS

Three batches of 100 broiler carcasses at 6 wk of age and 4 batches of 100 broiler carcasses at 8 wk of age (of mixed gender) were obtained from commercial processing plants after defeathering. One hundred broiler breeder males at 52 wk of age were obtained from a university flock. One hundred White Leghorn hens at 102 wk of age were obtained from a commercial layer complex. Two flocks of 150 ACRBC broilers were raised to 8 wk of age. Day-of-hatch ACRBC chicks were obtained and were reared at the University of Georgia under simulated commercial management conditions in an environmentally controlled house. All live birds were transported to the pilot processing plant in plastic coops, held overnight without feed and water for approximately 14 h, and euthanized by electrocution the following morning. Each carcass was hung by the feet in a shackle, and the abdominal cavity was opened and carefully inspected for the presence of an unabsorbed yolk sac. The antimesenteric side of the midileum segment of the small intestine was located and examined for the presence of a yolk stalk (Meckel's diverticulum). The abdominal cavity was then inspected for the presence of an unattached unabsorbed yolk sac. Carcasses with obliterated yolk stalks or stalks with no measurable yolk material (<0.5 mm) were categorized as normal. Those with unabsorbed yolk sacs were further separated into 2 groups: those attached by the yolk stalk and the small intestine and those unattached and located within the abdominal cavity. Yolk sacs were classified by size: 1) small (<2 mm in diameter), 2) medium (2 to 10 mm), and 3) large (>10 mm). The experimental unit was each individual carcass examined. These binary yolk sac incidence data were coded as 0 for the absence of a yolk sac or as 1 for the presence of an unabsorbed yolk sac. Similarly, yolk sacs that were located unattached to the yolk stalk were coded as 0, and yolk sacs that were located attached to the yolk stalk were coded as 1. These data sets were analyzed under the GLM procedure of SAS software (SAS Institute, 1998). The main effect of the model was carcass type (broiler, broiler breeder rooster, Leghorn hen, and ACRBC broiler males and females). The means for carcass types were separated using Tukey's Studentized range (honestly significantly differences) test (SAS Institute, 1998). For all analyses, significance was determined at $P < 0.05$. Yolk sac size classification was not subjected to statistical analysis.

RESULTS AND DISCUSSION

From the 297 6-wk-old broiler carcasses examined, 54% of the yolk stalks were categorized as normal with no detectable yolk sac, whereas 35% of the broilers had an unabsorbed yolk sac attached to the yolk stalk, and 12% had yolk sacs that were unattached (Table 1). Of the 103 unabsorbed yolk sacs attached to yolk stalks, 78% were classified as small, 21% were classified as medium, and 1% was classified as large. Of the 35 unabsorbed and unattached yolk sacs, 40% were classified as small, 57% were classified as medium, and 3% were classified as large. From the 403 8-wk-old broiler carcasses examined, 49% of the yolk stalks were categorized as normal, whereas 31% had an unabsorbed yolk sac attached to the yolk stalk, and 20% of the yolk sacs were unattached. Of the 125 unabsorbed yolk sacs attached to yolk stalks, 88% were classified as small and 12% were classified as medium. Of the 80 unabsorbed unattached yolk sacs, 24%

Table 1. Unabsorbed yolk sac incidence from broilers, broiler breeder roosters, Leghorn hens, and ACRBC[1] broilers

	Broilers		BB roosters[2]	Leghorn hens	ACRBC males	ACRBC females
	6 wk	8 wk	52 wk	102 wk	8 wk	8 wk
Normal, no yolk sac						
n[3]	159/297	198/403	73/100	88/100	115/150	113/150
Sampled[4] (%)	54[b]	49[b]	73[a]	88[a]	77[a]	75[a]
Yolk sac, attached						
n	103	125	8	8	5	9
Sampled[4] (%)	35	31	8	8	3	6
Yolk sacs[5] (%)	75[a]	61[a]	30[bc]	67[ab]	14[c]	24[bc]
Unattached[6] (%)						
Small (<2 mm)	78	88	100	75	60	90
Medium (2–10 mm)	21	12	0	13	40	10
Large (>10 mm)	1	0	0	13	0	0
Yolk sac, unattached						
n	35	80	19	4	30	28
Sampled (%)[4]	12	20	19	4	20	19
Yolk sacs (%)[5]	25[c]	39[c]	70[ab]	33[bc]	86[a]	76[ab]
Unattached (%)[6]						
Small (<2 mm)	40	24	58	50	47	46
Medium (2–10 mm)	57	76	42	25	37	46
Large (>10 mm)	3	0	0	25	16	8

[a–c]Percentages within a row with different superscripts differ significantly ($P < 0.05$) by ANOVA.

[1]ACRBC = Athens-Canadian randombred control.

[2]BB = broiler breeder.

[3]Numbers in denominator indicate the number of carcasses from which the presence of a yolk sac was examined.

[4]Percentages are out of total number of carcasses examined.

[5]Percentages are out of the total number of unabsorbed yolk sacs detected (attached + unattached).

[6]Percentages are out of number of yolk sacs recorded as either attached or unattached.

were classified as small and 76% were classified as medium.

Overall, for 6- and 8-wk-old broilers, approximately half (51%) were categorized as normal with a completely absorbed yolk sac, whereas the remaining broilers had more unabsorbed yolk sacs that were attached (33%) to the intestine than were located unattached (16%) within the abdominal cavity (Table 1). However, for broiler breeder roosters, Leghorn hens, and the male and female ACRBC broilers, approximately 75% of the carcasses sampled had completely absorbed yolk sacs. It has not yet been determined what factor accounts for the significantly higher ($P < 0.05$) incidence of unabsorbed yolk sacs in modern broilers at 6 and 8 wk of age compared with broiler breeder roosters, laying hens, or ACRBC broilers. A lower incidence of yolk sac recovery in breeders and layers may be due to continued absorption of yolk sacs after 8 wk of age. Another possible explanation is that the restrictive feeding and lighting (photoperiod of 16 h of darkness) programs that breeders and Leghorn hens are subjected to during rearing may have an influence on yolk sac use. The ACRBC broilers had a high incidence (76%) of completely absorbed yolk sacs, and these carcasses were sampled at the same age as the 8-wk-old commercial broilers and reared under a 23L:1D of dark photoperiod. Thus, a younger age is not the only contributing factor for unabsorbed yolk sacs at 8 wk of age. The rapid growth rate and high early feed intake level of commercial broilers in combination with long day lengths may prematurely restrict complete yolk sac use.

From the breeder carcasses with unabsorbed yolk sacs, a greater percentage of sacs were found to be unattached than attached to the yolk stalk, 19 compared with 8 (Table 1). This finding contrasts with the data collected from younger broiler carcasses, in which 33% of the yolk sacs were found attached to the small intestine, and 16% were located unattached. It is possible that during the extended production period for breeders (52 compared with 8 wk for broilers), attached yolk sacs are more likely to be absorbed or become unattached and locate within the abdominal cavity. Leghorn hens had the highest percentage of completely absorbed yolk sacs (88%), but for those unabsorbed yolk sacs that were detected, twice as many remained attached (8) to the small intestine than were found unattached (4) within the abdominal cavity. The fact that the hens had been molted and were almost twice the age of the roosters (102 vs. 52 wk) might have influenced the incidence of unabsorbed yolk sacs and their location. Gender of the ACRBC broilers did not affect any yolk sac parameters evaluated.

The reported incidence of unabsorbed yolk sacs posthatch differs dramatically among domestic avian species. At 7 d posthatch, the incidence of unabsorbed yolk sacs was reported to be 30% for chickens and 10% in geese, and yolks were completely absent in ducks (0%); yolk sac weight per 100 g of chick weight at 7 d posthatch was greatest for chickens (Jamroz et al., 2004). Genetic differences are speculated to be the main source of the lower incidence of unabsorbed yolk sacs in the ACRBC broilers compared with today's commercial broilers sampled at

the same age. Moreover, for ACRBC broilers, unabsorbed yolk sacs were more likely found unattached than attached to the yolk stalk. This finding is similar to the results found in the broiler breeder rooster carcasses sampled. The determination that the low incidence of unabsorbed yolk sacs for the ACRBC broilers (representing broiler stock genetics available in the 1950s) implies that the frequency of unabsorbed yolk sacs has changed over the past 50 yr of selection for the modern broiler.

The size of the unabsorbed yolk sacs that were located attached to the intestine were mainly classified as small, with from 60 to 100% being less than 0.2 mm in diameter. The overall incidence of attached yolk sacs classified as large (>10 mm) was low, with only the Leghorn hens having a percentage greater than 1%. The size of the yolk sacs that were detected unattached appears to differ between broilers and broiler breeder roosters. Broilers had 57 and 76% of the yolk sacs classified as medium, between 2 and 10 mm in diameter, whereas broiler breeder roosters had 58% of the unattached yolk sacs classified as small and the remaining 42% as medium.

At a high incidence of 49% for unabsorbed yolk sacs in broilers at the time of processing, yolk sacs could be a potential route for carcass *Campylobacter* and salmonellae contamination during processing. During a companion study, recent investigations (Cox et al., 2005) reported the recovery of *Campylobacter* and salmonellae from unabsorbed yolk sacs that were collected from commercial broilers processed at 6 and 8 wk of age. However, considering that the vast majority of the unabsorbed yolk sacs detected in broilers remained attached to the intestine (61 to 75%), and of these, 78 to 88% were classified as small, that leaves only 4% of the yolk sacs detected unattached and classified as large to result in carcass contamination if ruptured during evisceration.

ACKNOWLEDGMENTS

We are grateful for the assistance provided by Jerrie R. Barnett, L. Nicole Bartenfeld, Dianna V. Bourassa, Denise L. Brinson, Douglas E. Cosby, Fredda G. Murray, and Jeromey S. Jackson (USDA-ARS Russell Research Center, Athens, GA) for sample collection and recording data. We acknowledge the contributions of Dianna V. Bourassa (USDA-ARS Russell Research Center) for summarizing and statistical analysis of the data and preparation of the manuscript. Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the US Department of Agriculture.

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